AN EXPERIMENTAL ANALYSIS OF THE AMES TRAPEZOIDAL WINDOW ILLUSION

BY

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Abstract of Dissertation Presented to the Graduate
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AN EXPERIMENTAL ANALYSIS
OF THE AMES TRAPEZOIDAL
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BY

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The purpose of this research is to employ the method of Experimental Analysis of Behavior to analyze a human cognitive-perceptual experience known as the Ames Window Illusion. Cognitive-perceptual experience is defined in terms of a three-term functional relation known as the discriminated operant. A contrast is made between the interpretation provided by the Experimental Analysis of Behavior and the explanation offered by typical cognitive approaches. Salient variables affecting the probability of the Ames Window Illusion are identified. Research for and against the effect of reinforcers on visual processes is presented.

This study includes several single subject multi-element designs. Multiple regression and times series

techniques are used to analyze the results of each experiment. Only one of six experiments met the criterion for testing the difference between pre- and post-treatment stimulus control tests. The differences could not be analyzed using parametric statistics because the data violated the assumption of homogeneity of variance. Inspection of the differences lent support to the hypothesis that reinforcers change the probability of seeing the Ames Window Illusion and that the illusion can be interpreted as a discriminant operant.

Post hoc analysis of all eligible treatment phases, based on the assumption that the private responses necessary for seeing direction of rotation are infinitesimally small and the effects of change in illumination are relatively immediate, resulted in the conclusion that change in illumination was a reinforcer for all six experiments. No *post hoc* analysis of stimulus control gradients was performed. Recommendations for further research were made and the possible theoretical and practical value for education was discussed.

CHAPTER I
INTRODUCTION

The Experimental Analysis of Behavior is a method for determining the existence and describing the characteristics of relations between an active organism and its environment.

> Its concepts are defined in terms of immediate observations and are not given local or physiological properties. A reflex is not an arc, a drive is not the state of a center, extinction is not the exhaustion of a physiological substance or state. (Skinner, 1938, p. 44)

Since the inauguration of the Experimental Analysis of Behavior by B. F. Skinner in the 1930's, the method has been applied to a wide variety of animal species including homo-sapiens.

Work with homo sapiens has progressed in a wide variety of settings including prisons, mental institutions and schools. Despite its wide and growing influence, Experimental Analysis of Behavior is not without its critics. It is suggested that Experimental Analysis of Behavior is ill-equipped to address questions of cognition. By cognition is meant:

> all the processes by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used. It is concerned with these processes even when they operate in images and

> hallucinations. Such terms as sensation, perception, imagery, retention, recall, problem-solving, and thinking, among others, refer to hypothetical stages of aspects of cognition. (Niesser, 1967, p. 4)

The critics charge that since the Experimental Analysis of Behavior studies only observable behavior and that cognitive phenomena are internal, subjective, and hidden from view, then the Experimental Analysis of Behavior cannot study cognitive phenomena. However, although much activity of the organism occurs within the boundaries of its skin and is hidden from unaided observation, this activity can be studied by technologically extending the range of observation and by inferring the existence of such activity from observable behavior (Skinner, 1953, p. 282).

The important difference between cognitive and Experimental Analytic approaches to the study of psychology does not lie in their purported acceptance or rejection of natural events which may exist within the organism and beyond the current means of observation, since both recognize the existence of such natural events. The imporant difference between the two approaches lies in their differing definitions of subject matter. The subject matter for the cognitive psychologist is the hypothetical constructs and/or intervening variables (MacCoroquodale and Meehl, 1948) which cause the organism to search for, take in, and change information which directs in turn observable responding. The emphasis is upon finding the number and nature of the cognitive stages processing the environmental input.

On the other hand, the subject matter for those engaged in experimentally analyzing behavior is the functional relation between stimuli in the environment and the total activity of the organism. The activity of the organism includes that which is public and within the means of observation and that which is private and beyond the current means of observation. In this formulation "the environment stays where it is" (Skinner, 1974, p. 73) as does the activity of the organism. Rather than stressing the internal hypothetical or intervening stages which cause the organism to respond one way or another, the Experimental Analysis of Behavior emphasizes the transaction between environment and organism. Causes are not studies; functional relations between environmental stimuli and organismic activity are studied.

The Purpose of the Study

The purpose of this research is to employ the method of Experimental Analysis of Behavior to analyze a human perceptual experience known as the Ames Window Illusion. The Ames Window Illusion is chosen as the specific problem for this experiment because:

1. The Ames Window Illusion is a cognitive phenomenon.
2. The Ames Window Illusion is among the best known demonstrations in all of psychology.
3. The Ames Window Illusion is a partial foundation of significant educational theory and practice.

The Significance of the Study

This study is significant for three reasons: First, it suggests a variable which can affect the occurrence of a well-known visual illusion. Second, this study extends the Experimental Analysis of Behavior to events traditionally considered internal, subjective and causal. Third, since the Ames Window Illusion is a partial foundation of significant educational theory and practice, the use of Experimental Analysis of Behavior on this phenomenon provides insight into the use of Experimental Analysis of Behavior with cognitive educational problems.

Overview of the Study

The literature describing the Ames Window Illusion as a cognitive phenomenon, describing variables which affect the probability of seeing the illusion, describing the subject matter and method of Experimental Analysis of Behavior needed to investigate the Ames Window Illusion, and reporting the research on the Ames Window Illusion is reviewed in Chapter II. Chapter II also presents the question to be answered by the Experimental Analysis.

The strategies, tactics, and techniques used to answer the question raised in Chapter II are described in Chapter III.

The data are presented in Chapter IV.

The conclusions are stated and discussed in Chapter V.

CHAPTER II
REVIEW OF THE LITERATURE

The Ames Window Illusion is a cognitive phenomenon known to be related to measures of personality, stimulus variables and influenced by language. It is a well-known visual demonstration in psychology. It has been used to support a theoretical frame of reference which guided the development of a teacher training program. This chapter identifies the Ames Window Illusion as a typical cognitive phenomenon, identifies variables which are related to the occurrence of the illusion, presents Experimental Analysis of Behavior as an alternate interpretation of cognitive-perceptual phenomena in general and reports sensory research pertinent to an Experimental Analysis of the Ames Window Illusion.

The Ames Trapezoidal Window Illusion has been influential in both psychology and education. Avant and Helson (1973, p. 432) indicate it is among the best-known visual demonstrations in all of psychology. Besides psychology, Ames' literature is incorporated in educational theory and practice. Combs (1962, p. 4) indicates that the theoretical implications of the Ames demonstrations for education were first recognized by Earl Kelley (1947) in <u>Education for What is Real</u>. Kelley suggested that because we make

our perception of reality what it is on the basis of our past experience and our purposes, making children learn that for which they see no need may result in no learning at all (Kelley, 1947, p. 68).

The Ames Window Illusion and its theoretical framework offer partial support for Combs and Snygg's (1959) Perceptual Psychology. Their position is "All behavior without exception is completely determined by, and pertinent to, the perceptual field of the behaving organism" (Combs and Snygg, 1959, p. 20). This theoretical orientation was the basis for the New Elementary Program begun at the University of Florida in 1967 (Combs, Blume, Newman and Wass, 1974).

A Cognitive Phenomenon

Adelbert Ames published in the cognitive tradition. Cognition refers to "all the processes by which the sensory input is transformed, reduced, elaborated, stored and used . . . (these processes) refer to hypothetical stages of aspects of cognition" (Niesser, 1967, p. 4). Cognitive psychologists adopt objective methods to infer the existence of hidden intervening variables and hypothetical constructs from publicly-observable behavior.

Ames adopted objective methods to study subjective private events which are conceived to be causes of behavior. He held that what we see (a subjective event) is determined by unconscious learned assumptions (other subjective events) and that we act on what we see (Ames, 1951). To demonstrate the effects of unconscious learned assumptions

on perception, Ames created the Trapezoidal Window Illusion. He recognized that a trapezoid in the fronto-parallel plane projected an image on the retina similar to the image of a rectangle at an angle to the fronto-parallel plane. (The fronto-parallel plane is a surface a distance from an observer and perpendicular to the observer's line of sight.) He reasoned that if there were unconscious assumptions, then a person living in a rectangular world would unconsciously learn to interpret the projected image of a trapezoidal shape at one angle to the fronto-parallel plane as a rectangular shape at a different angle to the fronto-parallel plane. Verbal reports of the rotating trapezoidal figure made by subjects who have had the opportunity to develop unconscious assumptions about the images projected by rectangles at a slant supported Ames' hypothesis that unconscious learned assumptions determine what we see. The rotating trapezoidal figure was reported as an oscillating rectangular figure.

Allport and Pettigrew (1957) provided additional support for the Ames' hypothesis using Zulu tribesmen in a cross-cultural study. They reasoned similarly to Ames. If there were unconscious learned assumptions, then a person living in a world with no rectangles would not unconsciously learn to interpret the projected image of a trapezoidal shape at one angle to the fronto-parallel plane as a rectangular shape at a different angle to the fronto-parallel plane. There would be no cause to misinterpret the projected

image of the rotating trapezoid. Verbal reports of the rotating trapezoidal figure again supported Ames' hypothesis. Without past experience with rectangular shapes, there were no unconscious assumptions about rectangles to provoke a misinterpretation of the trapezoidal figure. The Zulu tribesmen saw a rotating trapezoidal figure.

Taken together, the work of Ames and Allport and Pettigrew shows that people with different past experiences perceive the same event differently. Past experience with a rectangular world results in a misinterpretation of a rotating trapezoid. Past experience with a rectangleless world results in a correct interpretation of a rotating trapezoid. These results support the conclusion that different unconscious learned assumptions in turn result in different subjective experiences of the same event.

Related Variables

Besides investigating the cognitive position that differences in unconscious learned assumptions are responsible for different subjective experiences, many investigators have attempted to discover variables which influence the probability of seeing the Ames Trapezoidal Window Illusion. Researchers have investigated personality measures, stimulus parameters, and language which effect the perception of the Ames Window Illusion. To date, no psychometrically determined personality factors have been linked in a reliable way to the likelihood of seeing the apparent reversals of the Ames Window (Stoegbour, 1967). However,

it has been found that Witkin's field dependence-independence dimension of psychological differentiation is related to the initial probability of seeing the Ames' Window Illusion. The greater the field independence the greater the probability of seeing the direction of rotation incorrectly (Zenhausern and Renna, 1976). Furthermore, perceiver type as measured by the initial probability of seeing apparent reversals, has been shown to influence subsequent perception of the Ames Window. However, perceiver type does not obscure the effect of stimulus parameters on the probability of seeing the illusion (Cahill, 1975).

Variations in the shape of the Ames Window target stimulus has suggested the ambiguity of depth cues contributes to the illusion (Day and Power, 1963). Linear perspective is a depth cue. It is the tendency for parallel lines to converge as the lines recede in the distance. Martinetti (1975) has found linear perspective to be a significant determiner of the probability of seeing the illusion. The greater the convergence, the greater the probability of seeing the illusion. Visual angle is also a variable determining susceptibility to the illusion. It is the angle subtended by an image projected on the retina when measured from the lens. It is identical to the angle subtended by the object when measured from the lens. The smaller the visual angle, the greater the probability of seeing the illusion (Zegers, 1964).

A number of investigators have identified personality measures, stimulus parameters and language usage as determiners of the probability of seeing the Ames Window Illusion. Ames presented a cognitive-perceptual explanation of the window illusion. The cause of the subjective experience was learned assumptions unconsciously interpreting the projected retinal image. However, Ames' cognitive-perceptual explanation of the window illusion is not the only explanatory framework for the illusion. The Experimental Analysis of Behavior may also provide an explanatory framework based upon its definition of subject matter and method.

Experimental Analysis of Behavior

The Experimental Analysis of Behavior is the science of behavior. Science is a method for studying relations. Behavior is a relation and Experimental Analysis is a method for studying it (Skinner, 1953, Chap. 2).

The prototype of behavior is the reflex. The reflex is a relation between a stimulus in the environment and a response of the organism. Because of its historical association with philosophy and physiology, the reflex is said to be unconscious, unlearned, and involuntary. However, these are negative definitions. The one positive characteristic which defines the reflex is the observed correlation between a stimulus and a response (Skinner, 1931). Behavior is a re-lation between a stimulus and a response of the organism.

Adopting the reflex as a prototype of behavior results in the abandoning of the concept of cause and the adoption of the concept of functional relation (Skinner, 1931, 1938, pp. 3-8). Replacing "cause" with "functional relation" has implications for both task and interpretations of psychology. Instead of finding the cause of behavior, the relation between environment and responding of the organism is discovered and described. Instead of symbolizing that part of the total activity of the organism found within the skin as causing behavior, concepts such as sensation, perception, cognition, motivation, and emotion are spoken of in terms of relations between environment and organism.

Behavior is a functional relation between environment and organism. Since relations can be partly described by the number of terms they include (Royce, 1961, p. 4), behavior can be partly described by the number of terms it includes. The reflex is a simple relation among only two terms--it is diadic. However, relations may hold more than two terms--behavior may be polyadic.

Two diadic relations which were observed to occur between environment and organism--between stimulus and response--having historical salience for the subject matter of psychology are the respondent and the operant. "Respondent" is a term implying a relation between a stimulus preceding a response and the response which follows (Skinner, 1938, p. 20). One of the characteristics of the operant is that it appears to occur without any correlation to a prior

stimulus, although such a relation may be shown to exist (Skinner, 1935, 1938, p. 21). "Discriminated operant" is a term implying a triadic relation holding among an antecedent stimulus, a response and a consequent stimulus (Skinner, 1969, p. 7).

All of the relations mentioned, be they respondent, operant, or discriminant operant, have strength. Since in the case of operant behavior, the operant response may occur without any apparent relation to antecedent stimulus events, the strength of the relation is directly proportional to its frequency or rate of occurrence (Skinner, 1935, 1966b). It has been shown that events immediately following an operant response effect the rate or probability of its occurrence by either increasing or decreasing its strength (Skinner, 1938, p. 62). Those events which increase the likelihood of an operant response are called reinforcers. Those decreasing the probability of an operant response are called punishers (Morse and Kelleher, 1977, p. 175). Knowing whether or not a stimulus which follows a response is a punisher or a reinforcer allows future prediction of the change in operant strength.

A stimulus regularly following a response is correlated with that response (Skinner, 1938, p. 22). Any stimulus regularly occurring prior to that same response is correlated not only with the response, but with the consequent stimuli as well. Knowing whether or not the consequent stimulus correlated with the antecedent stimulus is a

reinforcer or a punisher allows future prediction of the change in the probability of responding when the antecedent stimulus is presented to an animal. Antecedent stimuli correlated with punishers reduce the probability of the occurrence of the operant response. Antecedent stimuli correlated with reinforcers increase the probability of the occurrence of the operant response. Generally speaking, the antecedent stimulus is said to set the occasion for the response (Skinner, 1938, p. 22).

The three-term relation or contingency (Skinner, 1969, p. 7) identified above as the discriminant operant is a recent historical advance in the scientific study of animals. The three-term contingency extends the concept of lawfulness implicit in the notion of behavior first realized by the respondient to those activities previously identified with purpose, freedom, and unpredictability. Currently, volition purpose, freedom, and unpredictability fall within the purview of the discriminated operant (Skinner, 1966a, pp. ix-xiv, 1966b).

At a level of generalization which suggests all human experience can be expressed as an observed relation between environment and the total activity of the organism, the three-term contingency or discriminant operant is both an interpretation of human perception, memory, cognition, emotion, language, and society (Skinner, 1948, 1953, 1969, 1971, 1974) and an hypothesis (Skinner, 1931) in need of affirmation in a wide range of settings across a variety of

subjects and behavior (Johnston and Pennypacker, 1980, Chap. 15). As an interpretation of topics traditionally thought to be addressing activities existing solely within the skin of the organism, the Experimental Analysis of Behavior understands the private activity of the organism as it understands the public activity of the organism. As a part of an hypothesis, Experimental Analysis of Behavior treats both public and private responding as related to environmental stimuli. The task of experimental analysis is the same in either case: determine the existence and describe the characteristics of the behavior whether or not the responding is public or private.

The subject matter of Experimental Analysis of Behavior is markedly different from the subject matter of cognition. From the cognitive viewpoint, human experience is understood as the temporal end point in a series of internal causal processes which change sensory input. Experiments are designed to isolate causal processes in the series which modify the sensory input to correspond with the resultant subjective experience. Ames' work is an example. The subjective experience of the Ames Window Illusion is considered the result of unconscious learned assumptions interpreting an ambiguous image projected on the retina. His experiments and those of Allport and Pettigrew are designed to isolate unconscious learned assumptions which modify the sensory input to correspond with the resulting subjective experience.

Experimental Analysis of Behavior understands human experience to be a temporal unfolding of functional relations between environmental stimuli and organismic activity. Experiments are designed to determine the existence and describe the characteristics of the correlations between stimuli and responses as they occur over time (Skinner, 1938, Chap. 2). In this context, seeing is a discriminated operant in which the public antecedent and consequent stimuli are outside the organism's skin and the private events constituting the activity of the visual system are interpreted as private responses necessary for seeing. The existence and character of these functional relations are inferred from correlations between public responding of the organism which could occur if and only if the public antecedent, consequent stimuli, and private visual responding of the organism existed.

The advantages of an interpretation which takes the knowledge of the functional relations between public stimuli and public responding as the basis for discovering the relations between public stimuli and private events are two. First, with respect to perception, an interpretation of "seeing a thing in the absence of a thing seen" (Skinner, 1974, p. 82) is possible without attributing agency to the private events. The occurrence of hallucinations and illusions may be understood in the same way that the occurrence of a pigeon's pecking a key may be understood. The key pecking may be induced under one set of conditions,

made conditional upon yet other antecedent stimuli and maintained or changed with continuous or intermittent delivery of reinforcers. Just as public responding is not said to be the cause of its relation to public stimuli, neither is private responding said to be the cause of its relation to public stimuli. Just as public responding is necessary for the existence of a relation between public stimuli and public responding, so private responding is necessary for the existence of a relation between public stimuli and private responding. But in neither case are responses the causes.

The second advantage of an interpretation which takes the knowledge of the functional relation between public stimuli and public responding as the basis for discovering the relations between public stimuli and private events is that the results of investigating totally public behavior may serve as criteria against which to judge the similarity and dissimilarity of behavior which is only partially public.

It has been argued that until evidence to the contrary, there is no good reason to suggest that the occurrence of private events is not described by functional relations similar to those involving public responding (Skinner, 1945, 1953, pp. 257-258). Just as public responding characterized by a particular topography may be induced by particular antecedent stimuli and whose frequency of occurrence is maintained or changed through response contingent delivery of reinforcers, so private events of particular

topography whose frequency of occurrence is maintained or changed by consequent stimuli may be induced by particular antecedent stimuli and may be made conditional upon other antecedent stimuli through procedures of reinforcemment.

However, it is also possible that the occurrence of private events is not described by functional relations similar to those involving public responding. The strength and temporal patterning of public behavior may not necessarily co-vary in a simple way with either the rate of occurrence or temporal patterning of private events. For example, in the case of the Ames Window Illusion, it may be possible for the rate of public responding in the presence of clockwise rotation of an antecedent stimulus to take on any one of a number of arbitrary values depending upon the scheduled delivery of reinforcers. However, the rate of private responding in the presence of clockwise rotation of an antecedent stimulus is concurrent with the occurrence of one private event and that contingent delivery of reinforcers has no effect on the rate of occurrence of the private event.

Evidence for and against the strengthening effect of contingent delivery of reinforcers upon public behavior while the strength of the relation between antecedent stimuli and rate of private responding remains unchanged comes from sensory research.

Sensory Research

Evidence for the strengthening effect of contingent delivery of reinforcers upon public behavior while the strength of the relation between antecedent stimuli and private responding remains unchanged comes from a review of two studies, Herrnstein and van Sommers (1962) and E.E. Green (1962), by Donald Blough (1965).

Herrnstein and van Sommers (1962) trained two pigeons to peck a key at different rates in the presence of light stimuli of different intensities. In the presence of very low intensity stimuli, inter-response times of relatively long duration were reinforced. In the presence of moderately low intensity stimuli, inter-response times of somewhat shorter duration were reinforced. In general, the training consisted of differential reinforcement of shorter inter-response times in the presence of lower intensity illumination.

The inter-response time and stimulus intensity values were chosen so that if contingent reinforcement were successful in establishing functional relations between the public stimulus intensities and the different rates of public key pecking, then the relation of stimulus intensity to probability of public response would be best described by Stevens' power law which implies that "equal stimulus ratios tend to produce equal sensation ratios" (Stevens, 1957, p. 162). Upon examination of an obtained training curve, it was found that the stimulus-response relation closely approximated the power law. Therefore it was

concluded that delivery of a reinforcer contingent upon the chosen stimulus intensity and inter-response time values successfully established the desired arbitrary functional relation between antecedent stimuli and public responding.

Toward the end of training, stimulus control tests were performed. Testing stimuli were presented at various intervals under conditions of non-differential reinforcement. The testing stimuli took intensity values in between the intensity values of the training stimuli. Rate of key pecking was recorded in the presence of each testing stimulus, but inter-response times were not reinforced. It can be reasoned that if the rate of private responding necessary for seeing intensity was not effected by reinforcement, then the testing function obtained during the stimulus control test would not be described by the arbitrarily-chosen training function. On the other hand, if the rate of private responding necessary for seeing intensity was effected by reinforcement, then the testing function obtained during the stimulus control test would be best described by the training function.

Herrnstein and van Sommers reported that the function which best described the relation between the testing stimuli and the response rates obtained in their presence was the same as the function obtained during training between the training stimuli and the obtained rates of responding. Since the arbitrarily chosen training function, Steven's

power law, described the training stimulus-response and testing stimulus-response relation equally well, it can be concluded that the effect of delivery of a reinforcer contingent upon arbitrarily chosen public stimulus intensity inter-response time values were not limited to the specific public respondent behavior reinforced during training. They also effected the strength of the functional relations between antecedent stimulus intensity and the occurrence of the private event constituting that part of the sensory system necessary for all experiences of intensity.

However, after reviewing an article by Green (1962) which described the relationship between stimulus intensity and response probability in dark adapted animals as a modified Fechnerian log function and not Steven's power law, and recognizing that for most of the time the pigeons used by Herrnstein and van Sommers (1962) were dark adapted, Blough (1965) replotted both the training stimulus-response relation for both birds using an interval ordinate instead of the log ordinate used by Herrnstein and van Sommers (1962). The results showed that the conclusion drawn by Herrnstein and van Sommers could not be supported by their own data. The training stimulus-response function was not identical to the testing stimulus-response function. Indeed, the training stimulus-response function was the reinforced power function, but the testing stimulus-response function followed the Fechnerian log function which implies that "'equally often noticed differences are equal'" (Stevens,

1957, p. 155). Blough concluded that the effect of delivery of a reinforcer contingent upon the chosen public stimulus intensity inter-response time values did not effect the strength of the functional relations between antecedent stimulus intensity and the probability of the occurrence of a private event. It is important to consider those private events which constitute the relevant sensory processes when conducting sensory research.

More support for the lack of effect of contingent delivery of reinforcement upon the rate of occurrence of the private event necessary for sensory experience comes from an area of research called Stimulus Detection Theory (Green & Swets, 1966, 1974). Stimulus Detection theorists have developed indices of sensitivity based upon the relative rates of responding to two or more stimuli, rather than the absolute rates of responding to two or more stimuli. It is reasoned that the relative rates of responding co-vary with the probability of private responding. Although reinforcement may increase the absolute rate of public responding, because reinforcement does not increase the absolute rate of private responding, the relative rate of public responding will remain constant regardless of the reinforcement history. Other sensory studies have supported this view (Coombs, Dawes, and Tversky, 1970).

Evidence for the strengthening effect of contingent delivery of reinforcers upon public behavior having an effect on the strength of the relation between public

antecedent stimuli and private responding comes from the work of Nevin (1970) and Nevin and Nevin, Olson, Mandel and Yarensky (1975). They have used free operant procedures to study the sensory processes of pigeons and have shown systematic changes in sensitivity as a function of reinforcement history. Nevin et.al. (1975) conclude that the data from studies of multiple and concurrent schedules of reinforcement support the statement that history of reinforcement of public responding has an effect on the rate of occurrence of private events constituting sensory processes necessary for visual processes. In general, however, it must be concluded that the evidence presented for delivery of a reinforcer contingent upon the occurrence of a public stimulus-response relation increasing the likelihood of a contemporaneous public stimulus-private response relation is equivocal.

Summary

From the cognitive-perceptual point of view, human experience is understood as a subjective end point in a series of causal processes which change sensory input. Human experience is subjective and internal. It is the result of processes which change sensory input. In turn, human experience determines behavior.

The Ames Window Illusion has been traditionally interpreted from a cognitive perceptual point of view. The Ames Window Illusion is considered an internal subjective experience resulting from unconscious learned assumptions interpreting ambiguous stimulus images projected on the retina.

This study interprets human experience from the point of view of the Experimental Analysis of Behavior. In this context, human experience is understood to be a temporal unfolding of functional relations between environmental stimuli and organismic activity. Cognitive perceptual events are interpreted as a three term contingency or discriminated operant in which the antecedent stimulus sets the occasion for responding and the consequent stimulus increases or decreases the probability of responding.

The three term contingency may hold among terms which are all public and readily observable or it may hold among stimulus terms which are public and observable and response terms which are private and must be inferred from public responding. Changes in probability of private responding are inferred from changes in public responding if and only if the changes in public stimuli response relations are necessitated by changes in probability of the public stimuli-private response relations.

The Ames Window Illusion is a human cognitive-perceptual experience interpreted as a discriminant operant in which the antecedent and consequent stimuli are external to the organism and private events constituting the activity of the visual system are interpreted as necessary for seeing and located inside the organism.

Finally, it is hypothesized that delivery of a reinforcer contingent upon the public antecedent stimulus-public response relation called seeing direction of rotation correctly will strengthen the public stimulus-private

responding necessary for seeing direction of rotation correctly. Furthermore, it is hypothesized that delivery of a reinforcer contingent upon the public antecedent stimulus-public response relation called seeing direction of rotation incorrectly will strengthen the public stimulus-private response relation necessary for seeing direction of rotation incorrectly.

CHAPTER III
METHOD

Seeing clockwise rotation correctly is a functional relation between clockwise rotation of the public target stimulus and the occurrence of an unobserved private response. Seeing counterclockwise rotation is a functional relation between counterclockwise rotation and the occurrence of another incompatible unobserved private response. Because both mutually exclusive responses are private events and their occurrence is not directly recorded, the functional relations, seeing clockwise and counterclockwise rotation, correctly, must be inferred from the occurrence of publicly observable responses and stimuli.

The strategy used to determine if seeing direction of rotation correctly was a function of contingent delivery of a reinforcer involved four steps. First, a functional relation between publicly observable responses and stimuli that depend upon the existence of functional relations between private responses and publicly observable stimuli were established. Second, a contingent event was delivered as a consequence of the occurrence of the publicly observable stimulus-response relations. The results of delivering the consequent event were evaluated to determine if the

event was a reinforcer. Third, the probability of seeing clockwise and counterclockwise rotation correctly under conditions of non-differential reinforcement in a stimulus control test before and after contingent delivery of a reinforcer were compared to determine if the reinforcer effected the probability of seeing direction of rotation correctly.

Subjects

The ten female subjects were volunteers from EDF 3110, Human Growth and Development, during the summer quarter 1980. They were given extra credit for participating. They ranged in age from 17 to 22 years. All subjects reported normal or corrected normal vision. None reported the existence of astigmatism or problems with depth perception.

Apparatus

Experimental room

The experimental room was rectangular and divided into two unequal parts by a black curtain running the width of the room and parallel to its ends. The experimental space was the larger portion of the room; the control room was the smaller portion of the room.

Experimental space

The experimental space contained all the mechanical and electrical devices necessary for positioning each subject, detecting each subject's responding and presenting each subject with antecedent and consequent stimuli.

A double armed chair sat at one end of the experimental space and faced the black curtain located at the far end of the space.

The two response keys were fastened to a wooden support running in front of the arm chair. These mechanisms were used for detecting each subject's finger movement.

A set of headphones were placed on each subject's head. The headphones were used for delivering high and low tones as a consequence of too high or too low a rate of responding on the response keys and preventing unwanted sounds from reaching each subject's ears.

Black fiberboard walls began behind the chair, ran lengthwise down the experimental space and stopped short of the balck wall that marked the far end of the experimental space. The walls were used for preventing the subject from seeing and hearing extraneous events. It allowed each subject visual access only to his own half of the experimental space.

The target rotation mechanism was used for rotating a target at a pre-set speed and for changing the direction of the target's rotation according to the demands of experimental design. The target rotation mechanism, six feet long by one and a half feet wide, was painted black on the outside. It sat at the far end of the experimental space between the fiberboard walls and the black curtain. The target rotation mechanism's long side was parallel to the black curtain and perpendicular to the fiberboard walls.

Half of the mechanism sat to the left of the partition and parallel to the black curtain and perpendicular to the fiberboard walls. Viewing the target rotation mechanism from the top, two holes, three inches from either end, could be seen. A steel shaft with a receptacle drilled in the center to accept the steel axes of trapexoidal targets sat in each hole.

Two sets of trapezoidal targets were constructed from round metal stock. Each target was mounted on a metal axis which was attached to the lower side of the trapezoid along a line bisecting the target's horizontal side and parallel to both ends of the trapezoid. The target and its axis were painted flat black.

The first set of five targets was six inches long with a longer end of three and one half inches. The ends were painted white. The ratios of the painted ends to one another for three of the targets in each set of four were:

1.0 to .75
1.0 to .50
1.0 to .25

The fourth target in the set had end ratios of 1.0 to 1.0. A white paper envelope was placed over the ends. A rectangular strip of silver tape was attached to one side of the white envelope.

The second set of six targets was three inches long with a longer end of one and three-quarters inches. The

ends were painted florescent yellow. For the first three targets in the second set, the end ratios were identical to the end ratios of the first three targets of the first set. The fourth target in the second set was similar to the fourth target in the first set. It had an end ratio of 1.0 to 1.0 and was covered with a white paper envelope with a strip of silver tape on each side.

The fourth target in each set was used to establish seeing direction of rotation correctly. On the remaining targets the different end ratios indicated various degrees of linear perspective. These targets were used for controlling linear perspective and for testing changes in stimulus control gradients as a function of differential reinforcement. The targets with the end ratio of 1.0 to .50 were also used as training targets.

Two light fixtures, each with a five to seven volt light bulb, sat in front of the target, one fixture in front and to the right of the target, and one fixture in front and to the left of the target. Each light fixture was 18 inches away from the target, at the line of sight, and it directed light away from the subject and toward the target. The light fixtures were used for illuminating each subject's trapezoidal target. The intensity of the illumination of each bulb was measured from one-half inch at five foot-lumens at low intensity and at ten foot-lumens at high intensity. The intensity of each bulb could be varied together according to the demands of the design.

The black masking door was suspended from hinges anchored to the roof of the experimental space. The door could be drawn open or closed according to the demands of experimental design. It was used to obstruct each subject's view of the trapezoidal targets.

House lights were located in the ceiling of the Perceptual Laboratory. They could be turned on and off or their intensity varied by the experimenter. They were used to illuminate the laboratory prior to phase one of the experiment.

Control Room

A device located in the control room recorded the changes in the variables as well as the phases of the experiment. The control room also contained devices for scheduling the occurrence of antecedent and consequent events.

The event recorder possessed ten pens which could be deflected in one direction. Six pens were used to record changes in variables. Respectively, the first and fourth pens were deflected only when the inter-response time exceeded the upper or fell below the lower inter-response time limits. The second and third pens were deflected only when response key one and response key two were depressed. The fifth pen was deflected and remained deflected once each rotation of the target. The sixth pen was deflected and remained deflected during clockwise rotation of the target stimuli. As phase changes dictated by experimental design occurred, they were indicated in ink on the continuous paper output of the event recorder.

The contingency controller was a low-voltage, low-current device which acted as an interface between the subject and the high-voltage, high-current event recorder. The device determined when the subject was seeing correctly or incorrectly and delivered the consequent event according to experimental design. It also generated two audible tones, one high and one low, and delivered them through earphones to the subject when the subject's inter-response time violated either the upper or lower inter-response time limits. (See appendix.)

Procedure

Instructions

Each subject was told that only one eye was to be used during the experiment. They were asked to indicate which eye they preferred to use. The opposite eye was covered with sterile gauze.

Each subject was shown the response keys. Each key was demonstrated by pressing it at a rate falling within the inter-response time limits. The high and low tones indicating violation of the upper and lower inter-response time limits were presented to each subject through the earphones. After each subject sampled the tones, they were told to continuously press either one or the other response key at a rate that would avoid the presence of either the high or low tone. They were told that if they heard the high tone, it could be turned off by decreasing the rate at which they pressed either key. On the other

hand, if the tone was low, it could be turned off by increasing the rate at which they pressed either key. Finally, they were told that as the experiment progressed, a rotating target would appear at the far end of the experimental room. They were to indicate which direction it was rotating by responding on one lever when the target rotated clockwise and responding on the other lever when it rotated counterclockwise. It did not matter which lever they chose to indicate the direction of rotation just as long as they were consistent throughout the experiment. Any subject who was not clear about the instructions and asked a question, had their question answered. No mention was made of any other conditions or contingencies occurring during the experiment.

Reinforcer

The potential reinforcer was change in intensity of illumination. Change in illumination was selected for use as a contingent event because human subjects have a history of actively regulating intensity of illumination.

Behavioral and Measurement Units

Behavioral units were defined in terms of specific, empirically established relations between responding, antecedent and consequent stimuli. Responding was detected by the downward movement of one or two response keys. Response one was indicated by a downward movement of the response key one. Response two was indicated by a downward movement of the response key two. When either responding (response

one) occurs in the presence of an antecedent target stimulus rotating clockwise or responding (response two) occurs in the presence of an antecedent target stimulus rotating counterclockwise, the respondent is called seeing direction of rotation correctly. The remaining stimulus-response combinations describe a respondent called seeing direction of rotation incorrectly.

Temporal locus and repeatability are properties of responding used to detect the responses. The dimensional quantities are latency and countability. The fundamental units of measurement for these properties are time and cycle from which the measure of inters, frequency (cycle/unit time) and inter-response time (unit time/cycle) are derived.

<u>Coding of Recorded Data</u>

The data were recorded by six pens of an event recorder on continuously moving chart paper, Easterline Angus 1720 X. The first pen was deflected only when the inter-response time exceeded the upper inter-response time limit. The second and third pens were deflected only when response key one and response key two were depressed. The fourth pen was deflected only when the inter-response time fell below the lower inter-response time limit. The fifth pen was deflected once each rotation of the target. The sixth pen was deflected and remained deflected during clockwise rotation of the target stimuli. Changes in phase were indicated in ink on the continuous paper output of the event recorder.

The chart paper was ruled at equal intervals. It moved through the event recorder at the rate of one interval per second. After the experiment, each interval was consecutively numbered. The number of pen deflections within each interval for four of the six pens was counted and written on the chart paper. Pen deflections indicating violations of the upper and lower inter-response time limits were not counted because there were too few.

A five digit code number was created for each one-second interval. The code number consisted of one digit indicating the number of pen deflections for each of four pens and one digit indicating the phase. The code numbers were written on data coding sheets, punched on IBM cards and stored on magnetic tape.

Design

There were two sections to the study. The purposes of the first section of the study were to determine an appropriate duration for each experiment and make any corrections to the equipment which may be required. During this section a truncated stimulus control test was employed.

The purpose of the second section was to proceed with the study using the knowledge gained during the first section. During the second section, the full stimulus control test was employed.

During both sections, subjects were omitted from analysis if there were serious mechanical difficulties

or if, during the post-experimental interview, they indicated trouble seeing the targets.

Each experiment within a section was a single subject multi-element design. All experiments except the first experiment in section one consisted of the six phases listed below. The first experiment differed in that after Phase VI, Phases II, III, and IV were repeated.

Phase I: Differential Reinforcement of Inter-Response Times

The purpose of Phase I was to provide a steady baseline of responding necessary for establishing the behavior of seeing direction of rotation correctly. The black masking door was lowered and the house lights were turned off. The headphones remained silent only if inter-response times did not exceed 1/180th of a minute or fall below 1/240th of a minute. If a subject's inter-response time exceeded the lower limit, then the high intensity, low frequency tone was delivered through the headphones. If the subject's inter-response time fell below the upper limit, then a high intensity, high frequency tone was delivered to that subject through the headphones.

The inter-response time contingency was maintained throughout the remaining phases of the experiment. Phase II was commenced only after each subject exhibited a stable rate of responding.

Phase II: Establishment of Veridical Perceiving

The purpose of Phase II is to establish the behavior of seeing direction of rotation correctly. The black

masking door blocking visual access to the trapezoidal target was raised revealing a trapezoidal target with an end ratio of 1.0 to 1.0. A white paper envelope was placed over the ends. A rectangular strip of silver tape was attached to one side of the white envelope. The trapezoidal target rotated at a constant rate of nine revolutions per minute. The direction of rotation for each of the ensuing 360 degree rotations was programmed to change after eight consecutive rotations. High intensity illumination was maintained on the rotating trapezoid throughout phase II. Phase III was commenced only after the subject evidenced a pattern of veridical perceiving.

<u>Phase III: Stimulus Control Test One</u>

The purposes of Phase III were to determine if the existence of two relationships described as seeing direction of rotation incorrectly can be detected as a function of variation in a target stimulus property known as linear perspective and to act as a baseline for a comparison with stimulus control test two after contingent delivery of reinforcement. During the first set of experiments, only a single target was presented during stimulus control test one. The end ratio of this target was 1.0 to .50. During the second set of experiments, three targets were presented during stimulus control test one. The three targets were presented in the foloowing order:

1.0 to .75
1.0 to .25
1.0 to .50

The entire stimulus control test was performed under conditions of non-differential reinforcement.

Phase IV: Differential Reinforcement of Non-Veridical or Veridical Perceiving

The purpose of Phase IV is to determine if the contingent delivery of illumination can alter the likelihood of seeing direction of rotation correctly in the presence of the training target. The training target had an end ratio of 1.0 to .50.

Under conditions of differential reinforcement of non-veridical perceiving, continuously high intensity illumination of the training target was maintained if the subject saw direction of rotation incorrectly. If the subject saw direction of rotation correctly, the high intensity illumination was reduced 16 steps at the nominal rate of 12 steps per second until it reached the low intensity illumination. The intensity was increased in a similar fashion if the subject saw rotation correctly.

Under conditions of differential reinforcement of veridical perceiving, continuously high intensity illumination of the training target was maintained if the subject saw direction of rotation correctly. If the subject saw direction of rotation incorrectly, the high intensity illumination was reduced 16 steps at the nominal rate of 12 steps per second until it reached the low intensity illumination. The intensity was increased in a similar fashion until it reached high intensity illumination, if the subject saw rotation incorrectly.

Whether or not a subject was differentially reinforced for veridical or non-veridical perceiving during Phase IV of an experiment was determined by entering a random number table. An even integer indicated the veridical condition. If the subject participated in more than one experiment, the alternate condition was instituted during Phase IV.

Phase V: Stimulus Control Test Two

The purpose of Phase V was to determine if the contingent delivery of illumination presented in Phase IV altered the probability of seeing rotation correctly in the presence of the control test stimuli presented in Phase III. The second stimulus control test is identical to the first.

Phase VI: Establishment of Veridical Perceiving

The purpose of this phase was to determine if seeing rotation correctly remains under stimulus control of rotation of an unambiguous stimulus. Phase VI is identical to Phase II.

Post Experimental Interview

The post experimental interview was conducted with each subject immediately after she completed her last experiment. The interview consisted of a period of questioning followed by a brief reading of the subject's performance record made by the event recorder during their experiments. The following is the list of questions asked

during the first part of the interview.

1. Are you feeling all right?
2. What happened during the experiment?
3. Did you have any trouble seeing the targets?
4. Did you notice any changes in the intensity of the illumination?
5. Could you tell if the change in light intensity was related to anything else? If so, what?

The Hypotheses

The following hypotheses are tested in order. For any single experiment, if one of the null hypotheses is not rejected, then the remainder are not tested. If a significant correlation between proportion of responses on key one and direction of rotation is not found during Phase II, then seeing rotation correctly or incorrectly could not be established and there was no way to identify when and when not to deliver the contingent event during Phase IV. If a similarly signed significant correlation was not found between proportion of responses on key one and direction of rotation during Phase VI, then the data are uninterpretable. If there was not a significant change in the probability of seeing correctly during Phase IV, then the contingent event could not be considered a reinforcer and there was no reason to test the difference in the stimulus control gradients.

The hypotheses are stated for those single subject experiments in which seeing direction of rotation correctly is reinforced and then again for those single subject experiments in which seeing direction of rotation incorrectly is reinforced.

Reinforced for Seeing Correctly

1. There is no significant correlation between the probability of responding on response key one and the direction of rotation of the antecedent training target over a series of target rotations in Phase II.

2. There is no significant increase in the probability of seeing direction of rotation correctly over the series of target rotations when the contingent event is being delivered.

3. There is no significant increase in the probability of seeing direction of rotation correctly from Stimulus Control Test I to Stimulus Control Test II.

4. There is no significant correlation between the probability of responding on response key one and the direction of rotation of the antecedent training target over a series of target rotations in Phase VI.

Reinforced for Seeing Incorrectly

1. There is no significant correlation between the probability of responding on response key one and the direction of rotation of the antecedent training target over a series of target rotations in Phase II.

2. There is no significant decrease in the probability of seeing direction of rotation correctly over the series of target rotations when the contingent event is being delivered.

3. There is no significant decrease in the probability of seeing direction of rotation correctly from Stimulus Control Test I to Stimulus Control Test II.

4. There is no significant correlation between the probability of responding on response key one and the direction of rotation of the antecedent training target over a series of target rotations in Phase VI.

CHAPTER IV
RESULTS

Ten subjects participated in the study, five in section one and five in section two. The purpose of dividing the study into two sections was to use knowledge gained in section one to remove conditions of the experimental setting and or procedures which might interfere with adequate testing of this study's hypotheses. The performance of the five subjects employed in section one suggested two impediments to the adequate testing of the hypotheses. The first impediment was the limited duration of each experiment. The performance of the five subjects in section one suggested that the length of each experiment could be increased to approximately 50 minutes with no more than two experiments being run in any one time period. Each experiment in section two was about 50 minutes long. Each subject participated in two consecutive experiments separated by a 15 minute rest period.

The second impediment to adequate testing of the hypotheses identified in section one was the inability of three of the five subjects to see the antecedent target during the treatment phase. The data obtained from these three subjects was not coded or analyzed. To avoid

dropping subjects in section two of the study, a constant overhead source of illumination measured from one half inch at 40 ft.-lumens was directed at the targets. However, in spite of the addition of a source of overhead illumination, two subjects in section two complained of losing sight of the target during the treatment phase. The data from these two subjects were not coded or analyzed.

Rate of Responding

During each experiment, inter-response times were differentially reinforced beginning in Phase I and continuing throughout all remaining phases. Inspection of each experimental record showed very few violations of the upper and lower inter-response time limits in Phases II through VI. Once established in Phase I, the rate of responding remained within the bounds set by the upper and lower inter-response time limits--three to four responses per second.

Reducing the Amount of Data

A 50 minute experiment produced 3,000 one-second intervals. For the purpose of analysis, the number of observations were reduced by summing the number of pen responses for both response key pens in each interval across all intervals within a rotation. Since the target turns at nine rotations per minute, there are 6.7 intervals per rotation. The total number of observations available for analysis are equal to the number of target rotations or

approximately 15 per cent of the total number of one-second intervals. This method of reducing the data used all the information available.

Construction of Dependent Variables for Statistical Analysis

The procedure employed to reduce the amount of data created cyclicity in the data. Because there is a fractional number of one-second intervals per rotation and the coding procedure required that each interval belong entirely to one and only one rotation of the target, the number of intervals per rotation was not constant but cyclical. The pattern of intervals per rotation is a repetitive 'seven, seven, six.' Since the total response rate was maintained between three and four responses per second, the number of responses attributed to every third rotation would be systematically smaller by one seventh. The systematic error created by coding fractional intervals as whole intervals was corrected by making all dependent variables proportions. Proportions were corrected for systematic differences in the total number of responses per rotation by producing a common scale ranging from 0.0 to 1.0.

The dependent variable, probability of responding on response key one, was constructed to test whether or not there existed a functional relation called seeing direction of rotation correctly (hypotheses one and four). For each rotation, the probability of responding on response key one was derived by dividing the number of responses

on response key one by the total number of responses on both response keys.

The dependent variable, probability of seeing direction of rotation correctly, was constructed to test whether or not the contingent delivery of illumination changed the probability of seeing direction of rotation correctly (hypothesis two) and to test whether or not the contingent delivery of illumination changed the probability of seeing direction of rotation correctly from Stimulus Control Test I to Stimulus Control Test II (hypothesis three). For each rotation, the probability of seeing direction of rotation correctly was derived by adding the number of response on response key one occurring during clockwise rotation of the target stimulus to the number of responses on response key two occurring during counterclockwise rotation of the target stimulus and dividing by the total number of responses on both response keys. The probability of seeing direction of rotation incorrectly was derived in a complementary manner.

The Hypotheses

The hypotheses were tested in the following order. Hypotheses one and four were tested first, followed by hypothesis two and hypothesis three. Within any experiment, if a prior null hypothesis were not rejected, then the subsequent null hypotheses were not tested because the meaning of the subsequent tests are dependent upon the rejection of the prior null hypothesis.

Hypotheses one and four

Table 1 summarizes the results of testing the following null hypotheses for the single subject experiments.

1) There is no significant correlation between the probability of responding on response key one and the direction of rotation of the antecedent training target over a series of target rotations in Phase II.

2) There is no significant correlation between the probability of responding on response key one and the direction of rotation of the antecedent training target over a series of target rotations in Phase VI.

Change in direction of rotation of the antecedent training target can act as a discriminative stimulus and control the probability of responding on response key one. Consequently, the probability of responding on response key one was adjusted for change in direction of rotation and regressed on direction of rotation. (Both change in direction of rotation and direction of rotation are class variables.) The partial correlation coefficients between probability of responding on response key one and direction of rotation of the antecedent target over the series of rotations in Phases II and VI adjusted for change in direction of rotation are presented in Table 1.

It is possible that the residuals of data collected in a series are auto-correlated and violate the assumption of independence. The consequence of auto-correlated residuals is a severe under estimate of the error term. This, in turn, results in over-estimating the proportion of variance accounted for by the variables in the model

(Johnston, 1973, p. 76, Ostrom, 1978, p. 29). The partial coefficients have been corrected for auto-correlated residuals using the Cochrane-Orcutt procedure (Ostrom, 1978, pp. 39-40) when necessary and where noted.

Table 1

Partial correlation coefficients between probability of responding on response key one and direction of rotation of the antecedent target over a series of rotations in Phase II and VI adjusted for change in direction of rotation.

		Phase II			Phase VI		
Sub.	Exp.	r12.3	df	F ratio	r12.3	df	F ratio
				Section One			
0							
	1	.8662	1,19	79.66*	------	----	--------
1							
	1	.2833	1,37	3.29ns	-.6553	8,31	15.75*a
	2	.6531	1,18	16.76*	.4632	1,50	13.79*
	3	.7345	1,18	22.54*	-.1816	5,35	1.67nsa
				Section Two			
2							
	1	.9097	1,18	222.49*	.9334	1,28	324.09*
	2	.9251	1,21	273.73*	.8445	1,22	62.40*
3							
	1	.0471	1,26	0.06ns	.0840	1,27	0.24ns
	2	.7853	12,3	2.07ns	.4694	5,34	4.56*a
4							
	1	.8110	1,20	43.36*	.4854	1,27	16.87*a
	2	.9475	1,16	829.14*	.6830	1,25	28.27*

* alpha less than .05 two tail.
ns not statistically significant.
a corrected for auto-correlated residuals.

Seven of the ten tests of the partial correlation between the probability of responding on response key one and the direction of rotation of the antecedent targets over a series of rotations in Phase II rejected the null hypothesis and provide evidence to support the existence

of the functional relation, seeing direction of rotation correctly, in Phase II.

There were nine tests of the partial correlation between the probability of responding on response key one and the direction of rotation of the antecedent targets over a series of rotations in Phase VI because subject zero's first experiment contained no Phase VI. In seven of these nine tests, the null hypothesis was rejected, providing evidence to support the existence of the functional relation, seeing direction of rotation correctly, in Phase VI.

Comparison of the partial correlation coefficients between Phase II and Phase VI within each experiment shows that only five experiments showed evidence that the functional relation, seeing direction of rotation correctly, was reproduced with the same sign in both phases. These five experiments and subject zero's first experiment were eligible for the test of subsequent hypotheses. Subject zero's first experiment is eligible because Phase VI is absent and there can be no evidence to suggest that the functional relation would not exist if it had been tested.

Subject one's first and third experiments as well as subject three's first and second experiments were dropped from further analysis. For these experiments there was no evidence to support the establishment of the functional relation, seeing direction of rotation correctly, in both Phases II and VI. Because seeing direction of rotation correctly was not established with these subjects and experiments,

testing for a significant change in the probability of seeing correctly as a result of the contingent delivery of a consequent event is gratuitous. It is unreasonable to test the effect of a contingent event when that upon which the event is contingent can not be shown to exist.

Hypotheses two.

Table 2 summarizes the results of testing the following null hypotheses for the single subject experiments.

1) There is no significant increase in the probability of seeing direction of rotation correctly over the series of target rotations when the contingent event is being delivered.

2) There is no significant decrease in the probability of seeing direction of rotation correctly over the series of target rotations when the contingent event is being delivered.

Table 2 presents the expected sigh, obtained slope, confidence interval and degrees of freedom of the probability of seeing correctly regressed on the variate Nth rotation in a series of rotations. (Subject zero experiment one was designed to test both the above null hypotheses in a single experiment.) If the expected sign is negative, then the test was for a decrease in the probability of seeing correctly.

Figure 1 depicts one non-significant slope--subject two experiment one. Figure 2 depicts the statistically significant slope for subject two experiment two.

Table 2

Change in the probability of seeing direction of rotation correctly as a function of the Nth rotation in a series of rotations during the delivery of the contingent event.

		Treatment Phase			
Sub.	Exp.	E(sign)	b	Interval	df
			Section One		
0					
	1A	+	-.0017	(-.0039, +.0072)[b]	1,58
	1B	-	-.0003	(-.0042, +.0037)[b]	1,73
1					
	2	+	+.0039	(-.0078, +.0156)[b]	1,42
			Section Two		
2					
	1	+	+.0019	(-.0072, +.0039)[b]	1,105
	2	-	-.0023	(-.0036, -.0009)[b]*	1,108
4					
	1	-	+.0004	(-.0017, +.0239)[c]	1,85
	2	+	+.0013	(-.0027, +.0054)[b]	1,111

note: confidence interval is calculated for a one tail test at alpha less than .05.

* Alpha less than .05 for a one tail test.

b corrected for auto-correlated residuals.

c missing values, not corrected for auto-correlated residuals.

A slope which differs from zero is evidence for the existence of a treatment effect. All experiments whose subjects' performance during the treatment phase showed no slope different from zero were omitted from the subsequent test of hypothesis three. It is unreasonable to test whether or not a non-existent affect changes the probability of seeing rotation correctly in the presence of antecedent rotating targets since seeing correctly has

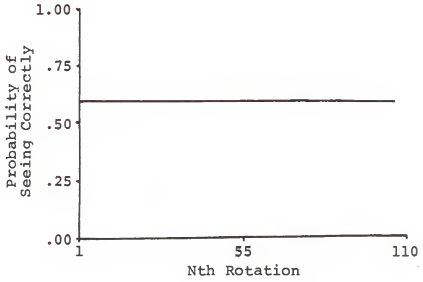

Figure 1. A statistically non-significant slope representative of six of seven slopes obtained during the treatment phase (Subject two experiment one).

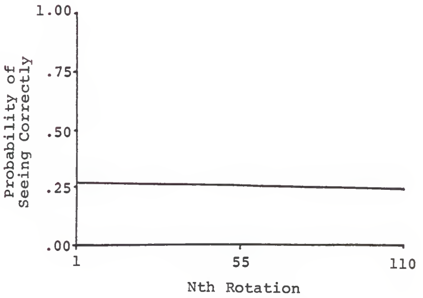

Figure 2. A statistically significant decline in the probability of seeing correctly over a series of 110 target rotations for Subject two experiment two.

Only the slope produced by subject two in experiment two gave evidence for the existence of a treatment effect. Consequently, this experiment was submitted to the test of hypothesis three.

Hypothesis three

Table 3 and Figure 3 present the contrast between Stimulus Control Test I and Stimulus Control Test II for subject two experiment two. The hypothesis, there is no significant decrease in the probability of seeing correctly from Stimulus Control Test I to Stimulus Control Test II, could not be tested with inferential statistics because of severe departure from homogeneity of variance among the treatment levels.

Table 3

The mean probability of seeing direction of rotation correctly for each target in Stimulus Control Tests I and II for Subject two experiment two.

Target End Ratios	Proportion X	Proportion Var	n
Stimulus Control Test I			
1:.25	.4916	.0038	46
1:.50	.4293	.2036	47
1:.75	.5432	.0128	49
Stimulus Control Test II			
1:.25	.5132	.0051	48
1:.50	.3481	.1151	46
1:.75	.4504	.0417	46

Table 3 shows the mean and variance of the probability of seeing rotation correctly for Stimulus Control Test I and Stimulus Control Test II.

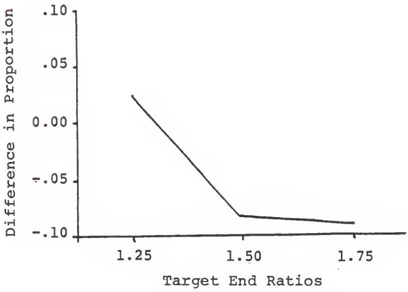

Figure 3. The mean difference in proportion for each target between Stimulus Control Test I and II for Subject two experiment two.

Figure 3 depicts the mean difference in proportion for each target between Stimulus Control Test I and II. The figure shows that the differences in two of the three targets were in the predicted direction. The smallest difference occured in the opposite direction.

Post experimental interview

The post experimental interview was conducted with each subject immediately after they completed their last experiment. The following questions were asked during the interview.

1) Are you feeling all right?
2) What happened during the experiment?
3) Did you have any trouble seeing the targets?
4) Did you notice any changes in the intensity of illumination?
5) Could you tell if the change in light intensity was related to anything else? If so, what?

None of the subjects complained of ill feeling during the experiment. Subject two complained of fatigue. Five

subjects, three in section one and two in section two of the study, whose data were not coded, analyzed or reported in this study, said that during the middle part of the experiment, they were unable to see the targets. All the subjects whose experiments were reported in this study reported they noticed changes in intensity of illumination. When asked if the change in light intensity was related to anything, all subjects except subject four said that the changes did not appear to be related to anything. Subject four said that the experimentor was manipulating the intensity of illumination.

Summary

The procedures used to establish the existence of the functional relation, seeing direction of rotation correctly, were successful in eight of the ten experiments. In only one of these eight experiments did the contingent delivery of illumination change the probability of seeing correctly. Although the mean difference in the probability of seeing correctly between Stimulus Control Tests I and II were in the predicted direction for two of the three targets and the smallest difference occurred in the opposite direction on the remaining target, these differences could not be tested with parametric inferential statistics because of severe departure from homogeneity of variance.

CHAPTER V
DISCUSSION AND CONCLUSIONS

This study employed the framework of Experimental Analysis of Behavior to explain a traditional cognitive-perceptual experience, the Ames Window Illusion. The Ames Window Illusion is interpreted as a discriminated operant. If this interpretation is correct, contingent delivery of a reinforcer upon a public stimulus-response relation will strengthen not only the public stimulus-response relation, but also the relation between public stimulus and private responding.

In ten experiments, fourteen of the nineteen tests for the existence of a correlation between direction of target rotation and response key pressing were statistically significant. Six of the ten experiments met the criteria for analysis of the effect of contingent delivery of increase in illumination on the probability of seeing direction of rotation correctly. The contingent delivery of increase in illumination was found to be effective in decreasing the probability of seeing direction of rotation correctly in one of six experiments. The effect of the contingency upon the stimulus control gradients could not be tested using inferential statistics because

of a severe departure from homogeneity of variance among the treatment levels. However, inspection of the means of the treatment levels gives support for the statement that contingent delivery of a reinforcer will strengthen not only the public stimulus-response relation, but also the relation between public stimulus and private responding.

Discussion

Five of the nineteen tests for the existence of a correlation between direction of target rotation and response key pressing failed to reject the null hypothesis. The variables which prevent the establishment of the detection of the correlation between direction of rotation and pressing key one or two are unknown. All five failures to reproduce the correlation were associated with two subjects. The inconsistent results in the presence of consistent conditions provides no indication of the variables which are responsible for the failure to reproduce the correlation.

In spite of the five failures, the existence of the functional relation, seeing direction of rotation correctly, was reproduced fourteen times. Seeing direction of rotation correctly was found to exist for all subjects in at least one phase of one experiment. Seeing direction of rotation correctly was found to occur in every experiment except subject three's first experiment. Finally, the functional relation was reproduced in both Phase II and Phase VI of five experiments.

These results suggest that unknown variables which prevent either the establishment or the detection of these relations in five of the nineteen tests remain to be discovered.

In five of the six experiments which met the criteria for analysis of the effect of contingent delivery of increase in illumination on the probability of seeing direction of rotation correctly, the test for the existence of the effect failed to reject the null hypothesis. Illumination was chosen as a likely reinforcer on the basis of Premack's reinforcement theory which suggests that preferred activities can be used to reinforce less preferred activities when preference is "measured in terms of the amount of time spent indulging in that event when permitted unconstrained access to it" (Dunham, 1977, p. 101). People generally spend more of their time under conditions of illumination conducive of seeing events than under conditions of little or no illumination which are not conducive to seeing events.

Since the contingent increase in intensity of illumination was shown to be an effect in one experiment, it is plausible to suggest that the failures to change the probability of seeing direction of rotation correctly in the remaining five experiments may be the result of some differences in subjects' sensitivity to the absolute intensity of illumination, the rate of change of intensity of illumination, or a possible differential sensitivity of each subject to the duration of the treatment.

Finding that contingent delivery of increase of illumination is a reinforcer for one subject in one experiment while not a reinforcer for the four remaining subjects and five experiments is evidence that the contingent delivery of illumination has no generality beyond this single experiment. Furthermore, there has been no replication. However, it does provide an opportunity to test the effect of a reinforcer on the stimulus control gradient in this case.

A severe departure from homogeneity of variance among treatment levels prevented the use of inferential statistics to test for the effect of the contingency of reinforcement upon the stimulus control gradients. Although the absolute magnitude of the variances about each stimulus control test mean changed from one control test to the next, the rank order of the sizes remained constant from one test to the other. This suggests that the variance about each stimulus control test mean was being controlled by the targets' degree of linear perspective.

Examination of the tables and the figures shows that the differences in two of the three targets were in the predicted direction. The smallest difference occurred in the opposite direction. These differences give some support for the statement that reinforcing a particular stimulus-response relation effects a larger class of private response public stimulus relations.

The analysis of these results was predicated on the interpretation that the Ames Window Illusion is a

discriminated operant in which the rotating antecedent target sets the occasion for private activity of the visual system necessary for seeing, and the change in illumination contingent upon public stimulus-response relation was a potential reinforcer which could change the probability of seeing the Ames Window Illusion over a series of target rotations. Another interpretation suggests a different analysis of the results.

Perkins (1970) presented the view that the law of effect applies to classical conditioning. It may be that the Ames Window Illusion is better interpreted as an unconditional response elicited by an unconditional stimulus which is made more or less valuable by one or another of the consequences of an observing response. However, this study was not designed to classify the Ames Window Illusion as either Pavlovian or operant. This author is in agreement with Schwartz and Gamzu (1977) when they say, "We have no solution...to the problem of classifying learning phenomena as one or the other type of conditioning" (p. 91).

However, Perkins (1970) has made a provocative statement. After citing Logan's (1966) micromolar theory, he says "The law of effect...seems quite workable as an explanation of all learned behavior change when responses are assumed to be of infinitesimal duration (i.e., when response selection is considered continuous)..." (p.133). This position suggests that because the internal responses

constituting the activity of the visual system are short in duration, the change in the strength of seeing the direction of rotation correctly may have occurred within a time span far shorter than the 6.7 seconds required to collect the first data point during the treatment phase. As a result, most of the treatment phase may represent steady state after a very brief transition. Indeed, the slopes in Table 2 show that this is the case for six of the seven slopes presented. Visual inspection of Figure 2 reveals a modest change in slope.

If it is the case that most of the treatment phase is a steady state after a very brief transition, then the appropriate post hoc test to determine whether or not the contingent change in illumination is a reinforcer is not the change in the psobability of seeing correctly over the series of target rotations during the treatment phase, but a comparison of the mean probabilities of seeing correctly in the presence of the same target stimulus under conditions of non-differential reinforcement (Stimulus Control Test I) and conditions of presumably differential reinforcement (Treatment). This test is possible with these data because the target stimulus used in the treatment phase was the last target used during the Stimulus Control Test I and there was no signaled transition between these phases.

The comparison was made for each of the seven treatment stimulus control test pairs. All seven differences in mean probability were in the expected direction. They

ranged in absolute value from .02 to .35. These data suggest that contingent delivery of illumination is a reinforcer, the private responses necessary for seeing direction of rotation are infinitesimally small, and the effects of change in illumination are relatively immediate.

The re-analysis of the data suggested by Perkins' (1970) comments does not discredit the interpretation of the Ames Window Illusion as a discriminated operant. Rather, it suggests that in the future, attempts to identify transition states with single subjects focus on smaller time slices than those used to aggregate data in this study.

Recommendations for further Research

It is recommended that the variables which prevented either the establishment or the detection of the functional relation, seeing direction of rotation correctly, be identified and controlled before continuing further research on contingencies which may reinforce this relation.

It is recommended that a systematic attempt be made to identify those variables which may make contingent delivery of increase of illumination a reinforcer for some subjects but not for others.

It is recommended that research proceed to determine if events other than increase in illumination can reinforce the probability of seeing direction of rotation correctly.

It is recommended that the analysis of transition states proceed within a much smaller time frame than the time frame

proceed within a much smaller time frame than the time frame used in this study.

Finally, because of the large amounts of data collected during a fifty minute experiment, it is recommended that future research use a computer to gather and display the data as each experiment progresses.

Conclusion

In conclusion, this research was modestly successful in demonstrating the utility of an Experimental Analysis of Behavior extended to events traditionally considered internal, subjective, and causal. The Ames Window Illusion was interpreted to be an instance of a three term relation called the discriminated operant. In an experimental setting the public stimulus--public response relation called seeing direction of rotation correctly was reproduced fourteen out of nineteen replications. Six experiments met the criterion for analysing the result of contingent delivery of an increase in illumination on two different relations, seeing direction of rotation correctly and seeing direction of rotation incorrectly. The delivery of an increase in illumination contingent upon seeing direction of rotation incorrectly decreased the probability of seeing the direction of rotation correctly for one subject. This finding, though not reproduced, supports the interpretation of the Ames Window Illusion as a discriminated operant.

Inspection of the means of the treatment levels gives support for the statement that contingent delivery of a reinforcer will strengthen not only the public stimulus response

relation, but it will also strengthen the public stimulus private response relation.

A cursory post hoc analysis based on the assumption of a brief transition state and long steady state during treatment reveals that illumination was a reinforcer. It suggests that future analysis of transition states use a smaller time frame than the time frame used in this study.

This study may provide theoretical and practical value for education. It provides theoretical value for education in two ways: first, it offers a theoretical interpretation of cognitive-perceptual phenomena which suggests that all human experience can be expressed as an observable correlation between environment and the ongoing activity of the organism; second, it provides a method consistent with subject matter. Cognitive phenomena are identified by varying events in the environment and looking for covariance in the activity of the organism.

This study may provide practical value for education in two ways: because it has been demonstrated that cognitive-perceptual phenomena exist as a correlation between environment and organism, educators may be sensitized to covariances which define other cognitive experience in educational settings; second, the study outlines an experimental setting and procedures which could be used to train prospective teachers in the methods of identifying meaningful cognitive-perceptual transactions.

APPENDIX
CONTINGENCY CONTROLLER

Function Description for Contingency Controller

Twelve functional blocks comprise the Contingency Controller. They are divided into three major classes. Input Blocks' main function is to obtain information from the outside world. Decision Blocks' main function are to use the outside information to make decisions. Output Blocks' main function is to produce some external effect.

Input Blocks

The Contact Conditioner receives noisy signals from two mechanical switches and debounces each one to provide two clean output signals to the Change Over Delay, Pulse Generator Set Re-set, and Relay Interface Circuits.

The Match Window/Response receives a signal from the Change Over Delay and from the Target Rotation Controller. It determines whether or not there is a match between direction of target rotation and one of two mechanical switches. It sends a signal to the four bit Conditional Up/Down Counter.

The Inter-Response Time Standard is divided into two parts: the upper and lower standard. Each receives clocking input from a double pole single throw mechanical switch and loading information from two two-position, four-pole rotary switches, two double pole single throw switches, and two double pole double throw switches. The parallel sixteen

bit output goes to the Inter-Response Time/Standard Comparator and the Led Interface.

Decision Blocks

Each one of the two Change Over Delays receives a primary debounced digital signal from one of two contact debouncers in the Contact Conditioner, a secondary debounced digital signal from the other debouncer in the Contact Conditioner, and an analogue signal from a variable resistor. It sends a timed signal to the four bit Conditional Up/Down Counter the first time it receives the primary signal. The circuit is reset by the receipt of the secondary digital signal. The duration of the timed signal sent to the Conditional Up/Down Counter is determined by the analogue signal from the variable resistor. Finally, one of the two Change Over Delays sends a signal to the Match Window/Response.

The Conditional Up/Down Counter receives signals from the Match Window/Response, both Change Over Delays, and a clocking signal. It sends a parallel four bit signal to the D to A Converter.

The Pulse Generator Set Re-Set receives two signals from the Contact Conditioner. It generates a 20 nanosecond and a ten nanosecond pulse. The leading edge of the ten nanosecond pulse trails the leading edge of the 20 nanosecond pulse by ten nanoseconds. The leading edge of the 20 nanosecond pulse inhibits the passage of the clocking pulses to the Inter-Response Time Counter and passes the inter-response time to the Inter-Response Time/Standard Comparator. The

leading edge of the ten nanosecond pulse clears the Inter-Response Time Counter ten nanoseconds before clocking is enabled by the trailing edge of the twenty nanosecond pulse.

The Inter-Response Time Counter receives three signals from the Pulse Generator Set Re-Set circuit. It generates a time count between responses and sends a parallel eight bit time count to the Inter-Response Time/Standard Comparator.

The Inter-Response Time/Standard Comparator receives parallel eight bit input from the Inter-Response Time Counter and two parallel eight bit inputs from the Inter-Response Time Standard. If eight bit input from the Inter-Response Time Counter is less than the eight bit lower standard input, then a signal is sent to the low tone generator of the Tone Generator and Pass. If the eight bit input from the Inter-Response Time Counter is more than the upper standard, then a signal is sent to the high tone generator of the Tone Generator and Pass. No signal is sent if the eight bit input from the Inter-Response Time Counter is within the lower and upper limits sent from the Inter-Response Time Standard.

Output Blocks

The Relay Interface receives two clean TTL compatible signals from the Contact Conditioner and provides two relay interfaces capable of passing one amp at 125 volts.

The D to A Converter receives a parallel four bit TTL digital input from the four bit Conditional Up/Down Counter and an analogue signal from a variable resistor. It converts the sixteen digital combinations to sixteen different output

voltage levels. The variable resistor adjusts the base output voltage of the D to A Converter.

The Led Interface receives parallel eight bit signals from the Inter Response Time Counter and two sets of parallel eight bit signals from the Inter-Response Time Standard. The Led Interface sends these signals to light-emitting diods.

The Tone Generator and Pass generates a low tone and a high tone. It receives two signals from the Inter-Response Time/Standard Comparator and passes either a high or low tone to the earphone output, depending upon which of the two signals it receives.

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BIOGRAPHICAL SKETCH

I was born in Glens Falls, New York. Although I moved about the state of New York during my pre-school years, I spent most of my school years living and going to school in Rockland County, New York. After completing high school, I attended the State University of New York, College at Oswego, where I earned a B.A. in psychology.

I met my wife, Sally Jeanne Leinthall Rist, at Oswego. We were married in Gainesville, Florida. We are the parents of two children, Lindsay Erin and Cassidy Logan.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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